

The Master Plan for Development of Geothermal Energy in Peru

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ABSTRACT

This paper describes the work done and conclusions of the geothermal master plan study did West JEC from March 2010 to February 2012 under the financial assistance to the government of Peru from the Japan International Cooperation Agency (JICA).

Prior to the activities of this project, the geothermal potential for power generation in the Republic of Peru was estimated in 3,000 MW or higher and in spite of this high potential till today there is no any geothermal field in exploitation in the country. The Master Plan for Development of Geothermal Energy in Peru was devised in order to provide the government of Peru with revised figure of the potential to generate power from geothermal resources and based on this potential to do an analysis of how geothermal energy could be introduced into the existing plans for renewable energy resources to participate in the energy mix of the country. The study was based upon a nationwide geothermal reconnaissance and in the detailed study of the power development plan for Peru to combine the results into a strategy to promote an accelerated geothermal energy development and exploitation program in Peru.

The nationwide reconnaissance helped to identify a large number site with hydrothermal indicators of which after several steps of screening, the number of sites of geothermal interest was reduced to 61. The geothermal potential in Peru was estimated in 2,860 MWe using the geothermal characteristics of these 61 sites. The regions with abundant geothermal resources were found to be in southern part of Peru. A mid/long-term vision for the energy mix strategy was devised and in which 1,000 MW of power participates in the energy chain by 2030. Considering the public sector, it is desirable that governmental organizations such as DGE and INGEMMET streamlines their organizations in the promotion geothermal energy and in the capacity building of Peruvian human resources while others players, such as Electroperú S.A are also expected to be directly involved. To promote geothermal development through the current FIT system inducing the private investments, it is desirable to set the base FIT electricity price as high as possible. However, will mean an impact onto the electricity tariff to consumers. To avoid this effect, it is desirable to implement other means of assistance and incentives to develop geothermal energy.

Although efforts have been made by the government of Peru after the formulation of the Master Plan, as of May 2014 only a few private companies make some progress in their geothermal development projects but still in the early stage of exploration. More aggressive contribution of the governmental organizations into the geothermal exploration and development is desired to promote the utilization of geothermal energy in Peru.

1. INTRODUCTION

In spite of the high estimation of geothermal potential in Peru there is no any geothermal exploitation in the country and one of the reason is the abundance of other sources of energy such and natural gas and potential for hydroelectric developments that impairs the need, and therefore the government support to develop geothermal resources. The country still is in need of know-how and experience in exploration and development of geothermal resources which make less attractive for the authorities to establish an environment for public and or private sector involvement in exploration/development drilling and construction of geothermal facilities.

Under these circumstances, in 2008 the law for promotion of electricity generation with renewable energy was enacted. This law targets 5% of total electricity generation utilizing renewable energy resources (solar, wind, biomass, geothermal, small-hydro (<20 MW)). According to this law, the government shall elaborate and review the national plan to develop and utilize renewable energy every two years. In the case of geothermal resources, currently there is not any development, the only concrete geothermal activities in Peru are the two Pre-Feasibility studies conducted for the Borateras and Calientes fields (JBIC-West JEC, 2008; JETRO-West JEC, 2008) and some participation of the private sector. A committee for the promotion of geothermal development has been created within the Peruvian government. Peru energy authorities requested technical assistance to the Japanese government to formulate a Master Plan for the development of geothermal resources of the country.

The Master Plan for Development of Geothermal Energy in Peru was formulated through a study project performed with funding by Japan International Cooperation Agency (JICA) from March 2010 to February 2012, in order to make the nationwide geothermal power development plan (Master Plan) for Peru in order to promote and accelerate the geothermal energy development and exploitation program in Peru (JICA-West JEC, 2012).

The Master Plan was formulated considering all factors including the geothermal resource potential in promising fields, the current and forecasted future situations of the electric power sector, and the framework established by the present policy/legal dispositions. The Master Plan involves recommendations aimed to promoting geothermal developments in Peru through the establishment of adequate national policies. In addition, a database of information related to the Peru's geothermal power development was constructed to serve the purpose of reference for the formulation of the Master Plan and of a platform upon which the Peruvian authority can proceed to make updates of the country geothermal capacity as new data become available. Technology transfer to the counterpart staff of the Directorate General of Electricity (DGE) of the Ministry of Energy and Mines (MINEM), Institute of

Geology, Mining and Metallurgy (INGEMMET) and other organizations in the MINEM was carried out all throughout the execution of the activities for this study.

2. ENERGY AND ELECTRIC SECTOR SITUATION

Peru's energy supply had significant participation of crude oil and derivatives (53%) and biomass (37%, mainly wood) in the 70's. Recently, however, there has been a strong involvement of Natural Gas (around 33%) while there has been a significant reduction in crude oil and derivatives (35%) and biomass (15%). On the other hand, the hydro, which reached its peak in 2004 with 17%, has fallen to the only 14% because of the penetration of natural gas in electricity generation. The participation of natural gas and derivatives (from the year 2004 the impact of Camisea can be clearly seen), which has helped decrease of the dependence of the crude oil and in recent years the smaller share of biomass (especially the wood) is also noticeable. On the other hand, the country's abundant water resources (about 58,000 MW) have not been sufficiently exploited.

The country's energy policy aims at securing energy self-sufficiency in a competitive environment through the promotion of private investment. Sector is expected to have a locomotive role for sustainable growth of the economy. Particularly the diversification of energy mix (through the reduction of oil dependence while increasing the use of natural gas, liquefied gas and renewables), promoting development of renewable energy resources (biomass, wind, solar, geothermal, tidal and hydropower capacity less than 20 MW), rural electrification, sustainable development of the sector with a minimum environmental impact, low carbon emissions and greater integration with the region's energy markets are a long-term vision of the MINEM for the energy sector.

The current electricity subsector activities are regulated for the Electricity Concessions Law (Law No.25844) and its Regulations, which entered in force since 1992. These rules are supplemented by the Act to ensure the Efficient Development of Electricity Generation (Law No. 28832) which entered in force since 2006 for the purpose of gradual improvement and adaptation of the legal framework along the evolution of the electricity market.

Figure 1 shows the actors involved in the electricity subsector and their interaction according to current regulations.

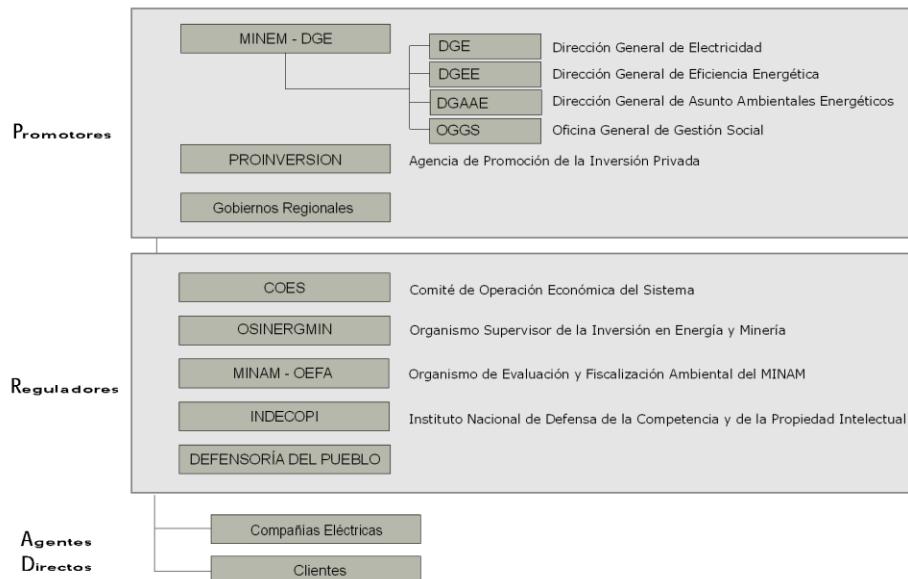


Figure 1: Participants in the electrical subsector of Peru

The wholesale market is free and has the participation of generation companies. In the wholesale market, power generators sell power to distribution companies or directly to large users (consumers of more than 2500 kW). The dispatch center, COES-SINAC, which is an organization composed of all generation and transmission and distribution companies (for each transmission system) has the function of commercial daily dispatch. The dispatch is planned every hour in merit order in the principle of optimal economic dispatch at the minimum cost.

To assure the liberalized wholesale and retail markets, the law guarantees free access to transmission networks. Users of the transmission and distribution lines, transmission and distribution charges, approved by OSINERGMIN must be paid. In late 2010, the transmission system in Peru was mainly composed of networks of 220 kV, 138 kV and 66/30 kV. The network is interconnected in 220 kV with a length of 2,200 km from north to south.

3. PROMOTION OF RENEWABLE ENERGY DEVELOPMENT

In policies for power sector, promotion of use of renewable energy resources is one of the pillars and the government is implementing concrete measures. For the country it is a requirement not only from the standpoint of view of the environment, but in order to meet the growing demand for electricity in the medium term it will be essential to use renewable energy resources. However, the country is highly dependent on the production of electricity from hydro resources and on natural gas, the latter recently showing a steep increase in the energy mix. Therefore, for energy security reasons, the government attributed a high degree of importance of the participation of renewable resources in the energy mix. The vision is to transform the energy mix into a one in which about one-third of the energy supply (including power generation) is based upon renewable energy sources.

The government established a 5% quota of renewable energy (RER: biomass, wind, solar, geothermal, tidal and hydropower up to 20 MW) in power supply of the coming five years. The government is implementing rules and incentives to promote the use of renewable energy resources and within the promulgation of the Law to Promote Electricity Generation with Renewable Energy (Law No.1002) in May 2008 and its Regulation (Supreme Decree No.050-2008-EM) enacted in October of the same year are the most important.

Under the Law and Regulations, the government carried out the first (2009) and second (2011) auctions of electricity supply with renewable energy resources in SEIN (Electric National Interconnected System) for the period of 20-30 years in the awarded price. The auction was conducted in the following manner:

- The country guarantees that the 5% of annual energy consumption should be covered by energy generated from renewable energy resources during the next 5 years.
- To meet the requirement, the country guarantees the payment of the awarded price in the auction for a period between twenty and thirty years. In case of that the awarded price exceeds the marginal cost of the spot market, the difference will be covered by a premium.
- The composition of energy by type of technology is defined accordingly to the National Renewable Energy Plan, projects with requested for concession.
- The bidding process is conducted by OSINERGMIN at the request of MINEM.
- For the determination of the Base Price, MINEM considers to assure the developers a return of not less than 12% as defined in Article 79 of the Electricity Concessions Law. Base Price is calculated by OSINERGMIN by type of generation technology with renewable energy resources.
- The Award Price shall be guaranteed to each successful bidders for the sale of its energy production, expressed in USD/MWh.
- The evaluation of bidders is independently done by technology type of renewable energy resources.
- The award is determined in merit order within the Base Price up to complete the share of each technology defined in the bid document to cover the total energy required.
- The term of validity is established in the Rules, within not less than twenty years nor more than thirty years.
- The call to auction will take place with intervals of 2 years.
- The sale of power generated with renewable energy resources in the short term market at marginal cost plus a premium is guaranteed, in cases where the marginal cost is less than the corresponding award price. The premium will be reflected in the price of electricity for end users.
- Be owner of a temporary concession is not a requirement for bidders.
- Preferential dispatch and free access to connection networks.

At the time of issuing the geothermal master plan to the Peruvian first auction of renewable energy resources electricity supply was conducted in order to have an installed capacity of 500 MW (converted from required energy 1,134 GWh/year at the capacity factor of 30%) with renewable energy resources other than hydro. The award was determined in February 2010 among 20 qualified bidders with 31 projects: 17 hydroelectric, 6 wind, 2 solar and 6 biomass. Finally, 26 projects have been awarded. The maximum prices set by OSINERGMIN previously were: hydro 74 USD/MWh, wind 110 USD/MWh, biomass 120 USD/MWh and solar 269 USD/MWh. As of 2014, the auction involving geothermal projects has never been conducted yet.

4. LEGAL FRAMEWORK FOR DEVELOPMENT OF GEOTHERMAL RESOURCE

To promote development of geothermal resources, the Organic Law on Geothermal Resources (Law No.26848) was promulgated in July 1997 and its Regulations in 2006. Later in April 2010, the new Regulation of Law No.26848 was approved with the objective of introducing private investment in developing this energy source and reduces the risk to them. Also, Ministerial Resolution No.191-2007-PCM established a Multisectoral Technical Commission.

According to the Organic Law on Geothermal Resources and its Regulations, geothermal activities are divided into the three development phases as shown in Table 1.

Development of geothermal resources should be done under the Organic Law of Geothermal Resources. However, for the electricity generation, it requires obtaining the concession for electricity generation under the Electricity Concession Law, and the concession for geothermal exploitation can be automatically extended for the years of the concession for electricity generation.

After implementation of new Regulation of the Organic Law of Geothermal Resources in April 2010, the multiple requests for authorization of geothermal rights have been presented to the MINEM. Applications of 98 projects were notified in the official newspaper by December 2011. MINEM gave authorization of 20 projects to four companies (Canadian, Australian, Peruvian and American) by February 2012. No application for concession has been officially made to date.

Table 1: Development phase of geothermal resources and geothermal rights

| Development phase | Activities | Geothermal rights | Terms |
|---|--|---|--|
| (i) Identification | Activity to determine whether the area has geothermal resources or not by means of observation of terrain, geology and geo chemical studies. | None | - |
| (ii) Exploration phase 1:realization of studies prior to the drilling of exploratory wells with a depth less than 1000 m. phase 2: realization of drilling of minimum of 3 exploratory wells | Activity to determine the dimensions, position, characteristics and extent of geothermal resources, including drilling of thermal gradient. | Requires Authorization | 3 years phase 1: 2 years phase 2: 1 year, possible to be extended one time for 2 years |
| (iii) development (exploitation) to power generation | Activity to exploit the geothermal energy with the commercial aims by means of steam, heat and fluid of high and low temperature and others | Requires Concession. In the event of power generation, the concession contract shall be extend automatically for the same period of the concession for electricity generation. | 30 years Possible to be extended for 10 years each time. |

5. ISSUES TO BE SOLVED FOR PROMOTING GEOTHERMAL POWER DEVELOPMENTS

As mentioned in the previous sections, the legal framework for geothermal resource development in Peru has been established with a system that postulates that the developments will be basically carried out by private sector. The application of the legal framework, however, has been just started from 2010. Thus for the developments to be actually enhanced, it is necessary for the Peruvian government to proclaim the policy and strategy for the promotion of geothermal developments. The aggressive governmental activities for the promotion are also necessary, and it is expected that flexible applications or revisions of the framework will be required according to actual situations.

The current issues to be solved for promoting the geothermal resource development in Peru can be enumerated as follows.

- Although the target for power generation by renewable energies including geothermal is set to be 5 % of the total electricity demand, the proportions to be supplied by each renewable energy sources, or a concrete development plans have not been formulated yet.
- The resource risk and risk in high initial cost, which are peculiar to geothermal, possibly prevent the progress of development by private sector. Thus it is necessary to consider options such as the improvement of the current legal system, or governmental participation to geothermal power generation project.
- The only existing incentive for promoting geothermal power generation projects is currently the fixed-price purchase system of generated electric power through the tender for renewable energy projects. The system has not been qualified as an effective measure in promoting the developments by private sector since the purchase price (the base price in the tender) has not been examined yet.
- There are not many experts on geothermal power generation and utilization in governmental institutions. Besides, collaborative partnership and information exchange for development promotion among the related institutions are not sufficient.

The Master Plan had been necessary to cope with the issues enumerated above. Consequently, the Master Plan was formulated to provide the recommendations and action plans, the geothermal development database, and the geothermal development plans.

6. DEVELOPMENT POTENTIAL BASED ON GEOTHERMAL RESOURCE

6.1 Overview of Geothermal Resource in Peru

From 1970's, reconnaissance and preliminary surveys/studies of the geothermal resource in Peru have been conducted by several Peruvian institutions including Electroperú, INGEMMET, the Proyecto Especial Tacna (PET), and the Instituto Peruano de Energía Nuclear (IPEN), with the cooperation of various international organizations (Battocletti, 1999).

Main land of Peru is located in the circum-pacific fire ring near the zone of subduction of the Nazca plate beneath the South American plate. This tectonic activity is the reason to the intense volcanic activity over million years that still is present up to very recent years. The Andes Cordillera, where most of geothermal fields and hot springs in Peru are situated, is a mountain belt resulting from the underthrusting of oceanic lithosphere adjacent to a continental margin. The Andes in Peru comprise two subparallel folds belts. The Western Cordillera is of Mesozoic-Tertiary age and the Eastern Cordillera of Late Paleozoic age. In southern Peru, where the fold belts diverge, they are separated by the Altiplano, which consists of a thick sequence of Tertiary molasse. The Andean Cordilleras are flanked to the east by the sub-Andean zone, which consist of continental sediments deposited on the Brazilian Shield, and to the west by the Precambrian Arequipa Massif, which may make up a large part of the Peruvian continental shelf (Keary and Vine, 1996).

Active volcanoes align in a single line forming a distinct volcanic front in southern Peru and northern Chile. However, in entire Neogene period, the volcanic centers are distributed almost all over the Altiplano. A wide distribution of volcanism is also consistent with high heat flow values observed not only near the Western Cordillera but in most part of the Altiplano. These imply that a much wider region has been under the influence of the volcanic activity, and a considerable amount of magmatic material should have been supplied to the crust beneath the Western Cordillera as well as the Altiplano (Kono et al., 1989). Kono et al. (1989) suggests that the volcanic activity in the Andes of southern Peru is perhaps distributed over a wide geographical extent covering most of Altiplano, and that the Altiplano corresponds roughly to the area of magma generation associated with the subduction of the Nazca plate beneath the South American plate (Figure 2). Presence of volcanic activity in Neogene in wide area of southern Peru implies that the occurrence of geothermal fields with high potential is expected.

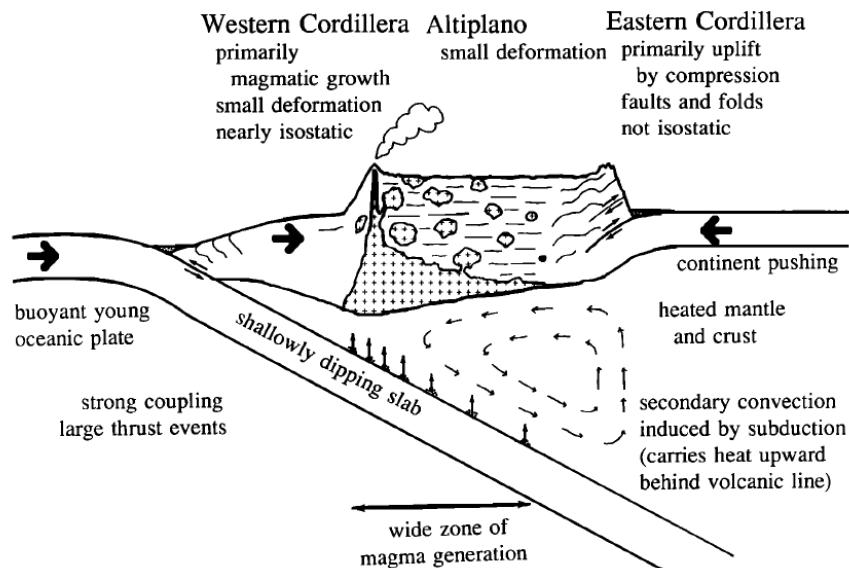


Figure 2: Conceptualization of the processes in the formation of the Central Andes (Kono et al., 1989)

6.2 Geothermal Resource Potential in Peru

In the Geothermal Map of Peru updated by INGEMMET (Vargas and Cruz, 2010), several important geothermal areas were defined. However, the geothermal (or hydrothermal) systems having the individual hydrological systems have not been delineated. In order to evaluate each geothermal field, the geothermal systems were selected based on the spatial distribution of hot or mineral springs and topography (Figure 3).

In the identification of geothermal sites, the isolated mineral and cold springs were ignored. Sixty-one (61) geothermal fields were selected in the whole country, but the fields more than half of them (38 fields) are within the Region 5 and Region 6. Among the 61 fields, 34 fields have one or more hot spring(s) with a discharge temperature higher than 60°C.

Based on the integration into conceptual models of the geoscientific studies done during the execution of this Master Plan Project to supplement the existing data (geology, geochemistry and geophysics), the potential of each of the selected 61 geothermal fields to generate electric power was calculated by means of the stored-heat - Monte Carlo method. Also the Monte Carlo analysis was applied to estimate number of production and reinjection wells required to exploit the potential. The results of the calculation of the resource potential allowed a classification of the 61 fields into the following four categories:

- Calientes and Borateras: According to the study reports of JBIC-West JEC (2008) and JETRO-West JEC (2008), in which the conceptual model of geothermal systems for resource potential estimation is based on detailed surface surveys including MT survey.
- Ancocollo and Tutupaca: Those two fields are selected as the most promising fields in this study, and the conceptual model for the fields for resource potential estimation is based on detailed surface surveys including MT survey.
- Eleven promising fields: The eleven fields are selected as the promising fields in this study, and the conceptual model for the fields for resource potential estimation is based on geological and geochemical surveys conducted in this study.
- Other fields (46 fields): The fields are delineated only by the special distribution of hot or mineral springs and topography. The resource potential is estimated with stored-heat method based on the rough assumption of temperature and volume of possible geothermal reservoir.

The distribution of calculated geothermal power potential in Peru is shown in Figure 4. More than half of the total resource potential exists in the Region 5. The total geothermal potential in Peru is estimated to be 2,860 MWe.

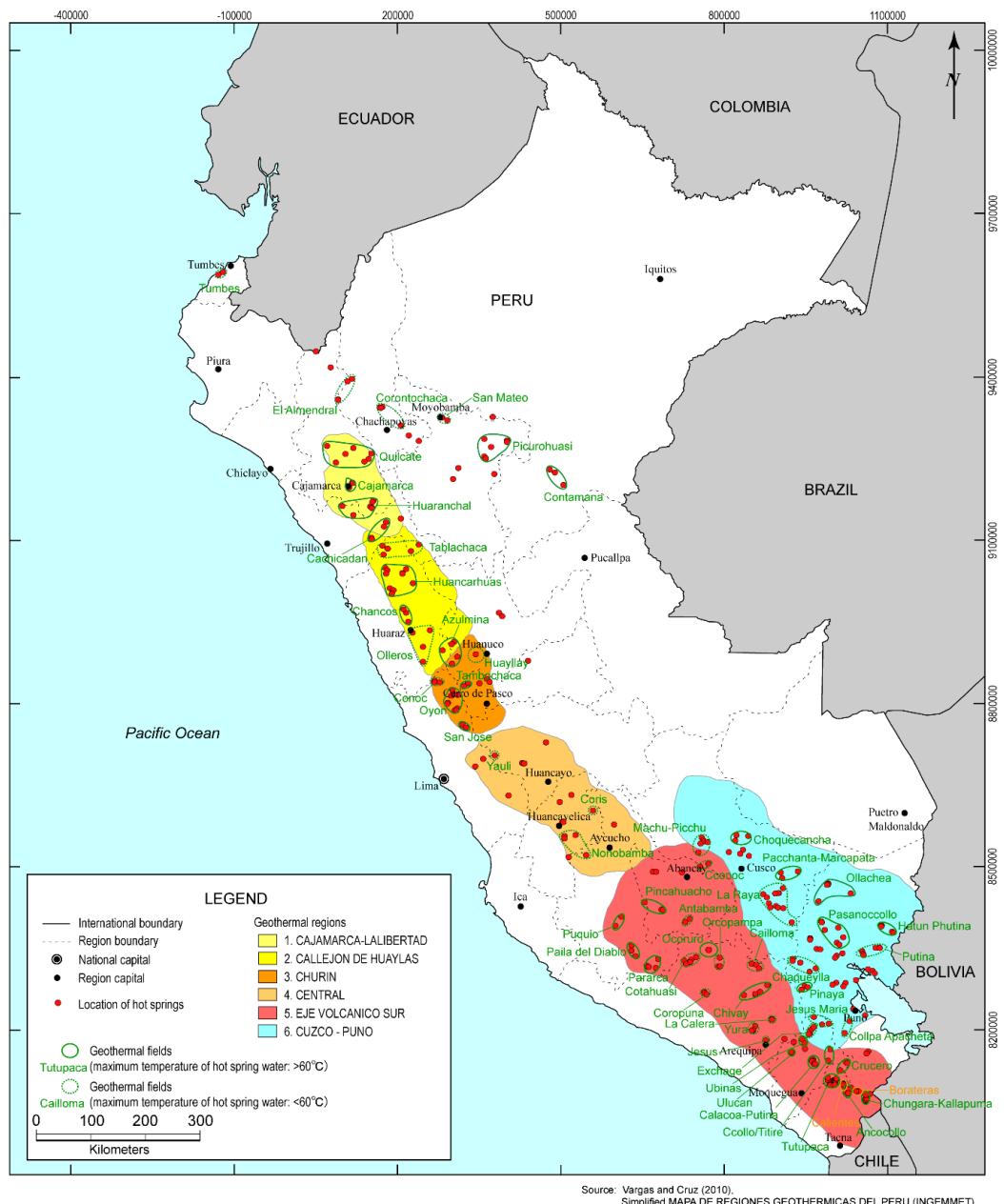


Figure 3: Location map of the delineated geothermal fields

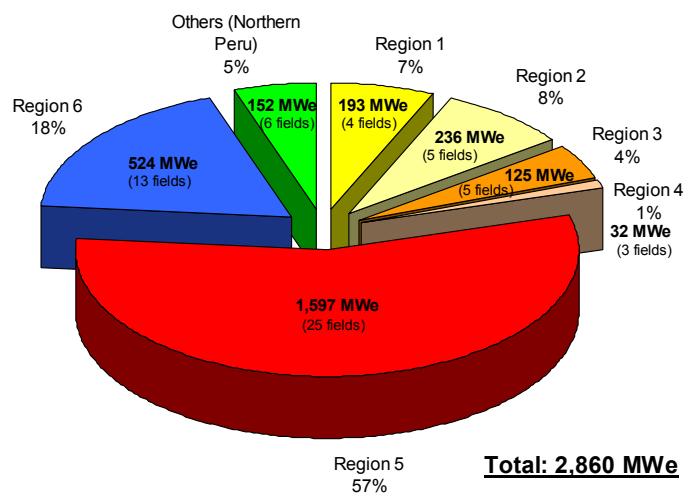


Figure 4: Geothermal power potential in each geothermal region

7. CONVINIENCE OF USING GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION

In general, geothermal energy is a clean reliable source of renewable energy which offers significant benefits when compared to other sources of energy:

- Environment friendly energy
- Reliable source of energy
- Indigenous source of energy
- Power generation business is economically viable to some extent
- Multi-purpose use of heat

The following is a list of some of the conveniences of using the geothermal energy of Peru for power generation.

- Electricity power development with various kinds of energy source is necessary to cope with growing energy demand. Among various renewable energies, geothermal energy is highly expected as a promising power source for base load of electricity since it can achieve stable supply.
- At present, natural gas fired power generations are carried out at low costs in Peru, and the power output is getting increased. Natural gases are demanded not only for power generation use but also for other purposes. Thus its domestic consumption is increasing. When geothermal power generation is realized, the consumption of natural gases for power generation use will be reduced, and the saved amount can be supplied to other purposes such as town gas demand. As natural gases are international merchandise, the saved amount can be sold to international market as LNG and the sales will bring foreign currency to Peru.
- Geothermal power generation will emit much smaller amount of CO₂ comparing with that of gas fired power generation that power supply is getting increased recently in Peru. Replacement of gas fired power plants with geothermal power plants will greatly contribute to the reduction of CO₂ emission.
- There exist abundant geothermal resources in southern part of Peru. On the other hand, there are poor amount of water resources in southern part of Peru since arid region widely spread over the southern part. In addition, although solar resources are relatively rich in southern part of Peru, wind power is not available except limited area in mountainous region.
- According to projections of demand and supply of electric power (up to 2016) for south area and other area (north and central), there will be enough supply than even optimistic demand in north and central area. On the other hand, the margin of the supply in south area will be only by “cold reserve (reserva fria)” power plant, which is the lowest priority of operation among power plants, in case of optimistic and medium demand projection. In this case, power with cheaper cost may be dispatched from central area to south. Consequently, geothermal power at promising geothermal fields in south area will make southern grid (Zona Sur: Apurimac, Cusco, Arequipa, Puno, Moquegua and Tacna) stable and contribute to improvement of the transmission losses and overall system stability, as well.
- The regions with abundant geothermal resources in Peru are cold districts at high-altitudes. Multi-purpose use of geothermal energy including room heating can be highly expected.

8. RECOMMENDATIONS AND ACTION PLAN

8.1 Target for Geothermal Power Development

As mentioned above, the total resource potential in Peru is estimated in 2,860 MW considering the most prominent 61 geothermal fields. The development of 735 MW could be possible in the most promising 13 geothermal fields. Moreover, since the geothermal developments in Peru will bring plenty national benefits including the saving of natural gas, therefore the utilizations of geothermal energy is recommended.

The quantitative target for power development utilizing renewable energies including geothermal resources has not been decided yet since “the National Plan for Renewable Energies” has not been approved and it is not open to public. However, the law for promoting power generation by renewable energies states that the power purchase with fixed price is guaranteed for up to 5% of total power demand (excluding hydro/micro-hydro power generations), and this could be regarded as the practical target for power generation by renewable energies. If the target for renewable energy power generation will be remained unchanged as 5% of the total power demand, it can be expected from the bidding results for renewable energy projects that the power generation by various renewable energies other than geothermal will cover the targeted amount of power demand. Thus it is desirable to increase the quantitative target of power generation by renewable energies in future.

It is desirable to increase the target power generation by renewable energies to be 10% of the total electricity demand. In the Republic of Chile, the neighboring country, a target goal was determined so that the amount of power generation by non-conventional renewable energies to achieve 10% of national power demand, by the year of 2024.

It is desirable to set the target goal of the power output by geothermal energy to be 50% of power generation by renewable energies, that is, the goal should be set as to supply 5% of total national power demand by geothermal energy. In this case, forecasting the growth of demand according to an optimistic scenario, and assuming the load factor of a geothermal power plant to be 85%, the target of power generation capacity by geothermal energy in 2030 will be 1,000 MW. This quantitative target of development, that is, to newly develop 1,000 MW in the coming 18 years, is not impractical, considering that the total resource potential in 13 promising fields is 735 MW as previously described, and considering that there are other fields to be exploited in the near future.

Recommendation: It is longed for geothermal resources to be developed as much as possible for power generation and other heat utilization purposes, as indigenous energy resources in Peru. The development will be started with resource exploration and will

take rather long time. However, to develop 1,000 MW geothermal power by 2030 is desired from the viewpoint of mid/long-term energy mix strategy.

8.2 Legal and Organization Framework for Geothermal Power Development

8.2.1 Legal Framework

In Peru, there exists the Organic Law of Geothermal Resources and its Regulation, which establish the framework for the promotion of geothermal development by the private sector. Under this framework, a number of requests for exploration right (authorization) have been requested. Currently, the authorization holders have the mandatory payment of small right fee of ever year as prescribed by the Article 62 of the Regulation of the Organic Law of Geothermal Resources. And in case of that the authorization holders do not advance their activities as planned, the guarantee (5% of the budget) presented by them for the phase II of exploration period will be executed as prescribed in the Article 17 of the Regulation of the Organic Law of Geothermal Resources. However, for the phase I for the exploration period, there is no penalty even though the authorization holders do not proceed their activities as planned. Therefore, if the authorization holders consider difficult to develop the project as private business, it may happen the case that they do not develop the fields but keep holding the authorizations. If this situation occurs in practice, it requires for the MINEM to strengthen their supervision on whether or not the exploration activities are being proceeded as planned.

On the other hand, if the authorization holders cannot proceed their exploration activities due to the high risks on resources, it is recommend that the governmental institution or other state-own enterprises participate on the exploration activities. In such case, the options such as the drilling by the public entity or the project implementation through the Public-Private Partnership should be considered.

This Master Plan study recommends the realization of the renewable energy resources auctions for geothermal generation projects in accordance with the law for electricity generation with renewable energies. However, in Peru, geothermal development is still in the phase of exploration, and so, the auctions for geothermal power generation have not been realized yet. In case of geothermal projects, it takes a long period for development, some measures should be considered to secure the power generation within certain years after the awarding. For example, to get the concession right must be a precondition for the participation on the auctions.

Recommendation: Any major problem does not been identified in the present legal and regulatory framework for geothermal development. However, in case of that it is revealed that the geothermal resource development only by the private sector is difficult; it is recommended to review and modify accordingly the related laws. The possibility of participation of the government or the public company for exploration stage and construction stage must be evaluated in order to reduce the resource risks and the investment burden for the private sector

8.2.2 Development System and Organization

It is expected that the power utility business in Peru will primarily evolve under private initiatives. In principle, so will be the geothermal development once it acquires certain momentum. Though it may follow such development path, those government bodies under DGE which are responsible for the power sector policy and the supervision of IPP must retain and develop wide range of technical experts related to the geothermal technology, including the legal and economical issues, so that they will be able to enact appropriate policies on the geothermal concession, to determine proper price level under FIT system or to provide proper supervision and guidance on the private developers during each stage of their activities such as exploration study, plant construction and its operation. Proper capacity building will not be realized if it consists of just sending bright young engineers to overseas training course. They need to go through actual projects in order to accumulate experiences. As the experts in the supervising organization gain more experience and knowledge in the geothermal technology, they shall bring more benefits to the country since they are capable to implement better judgment, policy and control on the development and use of the geothermal resource which is one of the precious assets of this country.

Under such circumstances, those developing countries which have been successfully introduced geothermal power plants, at least during the initial stages, opted a way that their public instruments undertook the projects, because they could absorb larger resource risk and they could utilize financial aid from bilateral and multilateral donors, thus the development cost can be reduced. During the early stage of the geothermal development in these countries, they also faced mounting problems including those for confirming resource quality and those on capacity building. Even after the construction of the first pilot plant, things did not go smoothly as they were encountered by numerous problems. In a way, these experiences showed difficulty of geothermal development, which makes private investors hesitating from entering green field development and in return proves the necessity for involvement of the public instruments. In case of Peru, as public entities which could undertake geothermal development are the state owned companies such as, 1), INGEMMET which has accumulated long experience in the geothermal study, 2), Perupetro S.A. which has knowledge on the drilling sector which also plays important role in geothermal development, 3), Electropetrol S.A. which was in past engaged in the geothermal study and can handle downstream side of the project. They could be reinforced with help from Universidad Nacional de Ingierencia when it comes to the technology pertaining to the geothermal power plant.

As geothermal development initiated by the public sector achieves success, it is expected that experience on the unique technical conditions pertaining to Peruvian environment such as those caused by high altitude (low atmospheric pressure and temperature) accumulates and a group of experts in this technology develops, which should enhance capacity of the governmental organizations who are responsible for supervising, controlling and advising the private developers as well as for setting the development policy.

Recommendation: It is desirable that, while the governmental organizations such as DGE and INGEMMET streamlines their organizations and promote capacity building in order to promote geothermal energy, the others expected to be involved directly such as Electropetrol S.A. should start building geothermal task team in their organizations.

8.3 Assistance and incentives for promotion of geothermal development

According to the study results in the Master Plan Project, recommendations on assistance and incentives to promote the geothermal power development in Peru are summarized as below.

- To promote geothermal development through the current FIT system inducing the private investments, it is desirable to set the base price as high as possible. However, it means that the impact on electricity tariff for consumers may become significant. To avoid that, it is desirable to implement other means of assistance and incentives.
- In case of geothermal development only by the private sector, it is recommended to provide them with the financial assistance thorough Two Step Loan to COFIDE, for example, utilizing the concessional loan. Additionally, tax incentives such as tax holiday can also work to promote geothermal development principally by the private sector.
- However, in many cases, the geothermal development only by the private sector is difficult. In such a case, it is recommended to evaluate, in early stage, the possibility of Public Private Partnership utilizing the ODA concessional loan for the portion of investment by the public company.
- It is desirable that the government conducts the resource exploration as a part of fiscal assistance. This contributes to reduce the resource risk, development cost and lead time for development for the private companies.

8.4 Action Plan for Geothermal Development

The yearly schedule of the action plan relating with all areas (legal framework, system/organization, supporting/assistance by the government and multipurpose use) for promoting geothermal developments in Peru is shown in Table 2.

In the yearly schedule, each action to be taken is classified into two groups, one of which is desired to be achieved in a short term, and the other is the actions to be continuously taken for medium or long term. As for the short-term objectives, first of all, the basic policy to promote geothermal developments should be clearly proclaimed. Secondly, proper management and appropriate instructions should be given steadily for the geothermal exploration and exploitation activities carried out by private sector. The items relating with the management or direction of the development activities by private sector are enumerated in the short-term objectives. In addition, the necessary items to prepare for the governmental direct participation (for example by a state-owned enterprise) to geothermal power generation projects are also listed in the short-term objectives. It is assumed that the short-term objectives shall be achieved within three years, since the resource exploration activities in the fields of which exploration rights granted in 2011 shall be basically completed in 2014 (exploration period of three years). The items such as actions to realize geothermal developments by state-owned enterprises, continuous capacity building for various organizations, additional resource potential study at unexplored area, are listed in the mid or long-term objectives.

Table 2: Action plans for each areas and yearly schedule

| | Short-term Target | | Long-term Target | | | | | | | | Note |
|--|-------------------|------|------------------|------|------|------|------|------|-------|--|---|
| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020- | | |
| Revision of targeted RE participation | | | ▼ | | | | | | ▼ | | present status: 5% of total energy demand |
| Tender for RE projects | ▼ | | ▼ | | ▼ | | ▼ | | | | every two years |
| Legal Framework | | | | | | | | | | | |
| - Enactment of policy | ████ | | | | | | | | | | National Plan for RE etc. |
| - Revision of Geothermal Law (as necessary) | ████████████████ | | ████ | | | | | | | | Management of development by private sector, etc. |
| - Revision of RE Law (as necessary) | ████████████████ | | ████ | | | | | | | | |
| - Guideline for natural and social environmental considerations | ████ | | | | | | | | | | |
| System/Organization | | | | | | | | | | | |
| - Capacity building to develop management | ████████████████ | | ████ | | | | | | | | DGE - INGEMMET |
| - Network for promoting geothermal | ████ | | | | | | | | | | MEM Geothermal Committee |
| - Database updating system | ████ | | | | | | | | | | |
| - Organization in state-owned utilities | ████ | | ████ | | | | | | | | Electroperú, etc. |
| - Capacity building of the public sector for their participation in geothermal | ████ | | ████████████████ | | | | | | | | |
| Support from the Government | | | | | | | | | | | |
| - Development finance system (TSL, etc.) | ████ | | | | | | | | | | COFIDE etc. |
| - Establishment of PPP scheme | ████ | | | | | | | | | | Financing at low interest, etc. |
| - Exploration by the public sector | ████ | | ████ | | | | | | | | |
| - Upgrade knowledge of geo-potential | ████ | | ████████████████ | | | | | | | | INGEMMET |
| Multi-purpose Heat Use | | | | | | | | | | | |
| - Management of hot water resources | ████ | | | | | | | | | | |
| - Legal framework for multi-purpose use | ████ | | | | | | | | | | |
| - Establishment of subsidy system | ████████████████ | | ████ | | | | | | | | |
| - Public demonstration project | ████ | | ████████████████ | | | | | | | | |

9. GEOTHERMAL DEVELOPMENT DATABASE

The collection and analysis of the data related to the promising geothermal field in Peru was carried out in this project. The geothermal development database was constructed based on the geothermal resource database by adding the other information about electric supply and demand balance, power grid, natural and social environmental issues, and so on. Thus, the database does not focus to the specific geothermal field to provide detail information of the field, but rather is comprehensive to provide the

general information of geothermal development in Peru and basic information for each geothermal field in the country. The geothermal development database can be utilized to search and update the necessary information regarding the geothermal development in Peru. The database is expected to assist the acceleration of geothermal development in Peru.

The database of the Peru Geothermal Master Plan has been created using the MS-Access relational database system. In a relational database different categories of data and information are stored in different tables that are linked by one-to-one and one-to-many relationships which allow for efficient and flexible data storage, with minimal duplication and considerable flexibility of data retrieval.

The geothermal manifestations in Peru were classified to 61 fields. In order to include information for isolated, scattered hot springs around the country that do not fall into one of the already recognized "fields", additional 12 groups, which combine with the 61 fields to make 73 different resource areas, was prepared. There is also one record for Peru country-wide information. Most of the geothermal fields include numerous hot spring areas scattered over the countryside, so each field has been subdivided into a number of separate "Sectors". Some of the 73 resource areas have only one sector (that is, there is only one hot spring area, be it small or very large). Some have more than 10 different sectors (that is, there are more than 10 different hot spring areas that may or may not be related one to another).

The data and information which are contained in the database is shown in Table 3. Regarding the whole Peru, the geothermal resource map, national grid system map, etc. are contained. Regarding the each geothermal field, data and information on geothermal resource, electric supply and demand balance, natural and social environmental issues, and other information are stored.

Table 3: Data and information in database

| Area | Category | Data and Information |
|------------|---------------------|--|
| Whole Peru | Geothermal resource | Geothermal resource map Coordinate of each field |
| | Electric sector | National grid system map |
| | Natural and social | Map of environmental protected area |
| | Others | Geothermal Law |
| Each field | Geothermal resource | Geological / Geochemical data Geothermal model Conditions and results of resource estimation |
| | Electric sector | Development plan for power plant and transmission line Access to the main power grid |
| | Natural and social | IEE results for promising fields, estimated GHG emission reduction, etc. |
| | Others | Status of application |

10. GEOTHERMAL DEVELOPMENT PLAN

In establishing the development plan of geothermal energy in all over the Republic of Peru, geothermal fields (61 fields) including the promising fields were examined and classified with adopting the evaluation criteria (resource potential, status of authorization for exploration, topography/access conditions and distribution of protected areas) for prioritization of development. Each geothermal field was classified into Rank A, Rank B, Rank C, Rank D and Others, based on the evaluation results. The results of development priority evaluations are summarized in Table 4. It can be expected that total 640 MW power generation would be achieved in the fields categorized in relatively high priorities (Rank A and Rank B).

Table 4: Result of development priority evaluations

| Rank for Priority | Description | Geothermal Field | Possible Power Output (MW) | Total Possible Power Output (MW) |
|-------------------|---|--|----------------------------|----------------------------------|
| Rank A | Earliest development is expected. (The development would be done even without any support from the government) | Tutupaca | 105 | 340 |
| | | Crucero | 70 | |
| | | Calacoa-Putina | 100 | |
| | | Pinaya | 35 | |
| | | Pugui | 30 | |
| Rank B | Followin the Rank A (The authorization for exploration is to be waited for.) | Chivay-Pinchollo | 150 | 300 |
| | | Ancocollo | 90 | |
| | | Ccollo/Titire | 35 | |
| | | Ulucan | 25 | |
| Rank C | Relatively early development is expected, but the resource potential is to be confirmed. | Cailloma | 5 | (60) |
| | | Huancarhuas | (30) | |
| | | Paila del Diablo | (15) | |
| | | Pararca | (10) | |
| Rank D-1 | The resource potential is to be confirmed. (Based on the existing data, high potential resource can be expected.) | 17 fields (including Chancos and Jesus Maria) | — | Unknown |
| Rank D-2 | The resource potential is to be confirmed. (Based on the existing data, the existence of high potential resource cannot be expected.) | 24 fields | — | Unknown |
| Others | Environmental impact of possible geothermal project should be evaluated. If the impact can be avoided or mitigated sufficiently, the development should be permitted. | 7 fields (including Borateras, Calientes and Chungara-Kallapuma) | — | >225 |

- Rank A: Among the promising fields chosen, five (5) fields where the authorization of exploration right has been already granted are categorized in this class. Early power development can be expected in the fields since the granted private companies are obliged to accomplish their exploration activities within three years.
- Rank B: Four (4) fields where the authorization of exploration right has not been granted are categorized in this class. The fields are next to the Rank A fields, and relatively early developments of geothermal resources can be expected in these fields.
- Rank C: Four (4) fields where the project economy is relatively low, or the fields where relatively high resource potential is expected and the exploration right has been authorized, are categorized in this class. The development scale in the fields except the 13 promising fields is conservatively assumed as 30 % of the estimated resource potential. Although the authorization of exploration right has been granted in these fields, it is desirable to continue investigations for resource confirmation or project feasibility.
- Rank D-1: The fields where reconnaissance survey has been done are categorized in this class. Additional resource surveys are necessary. In these fields, geochemical data show promising relatively high. Higher emphasis in resource study should be placed on Rank D-1 fields.
- Rank D-2: The fields where only simple survey has been conducted are categorized in this class. Much more studies are necessary. The existing data obtained so far do not show high promising level.
- Others: Four (4) fields are located in the vicinity of national parks or historical sanctuaries. Also, there were three (3) fields that exist inside of regional protected area in Tacna Province (Vilacota-Maure Regional Conservation Area).

An integrated plan for geothermal power development in Peru that aims to develop 1,000MW electricity by 2030 was devised in conformity with the objectives stated in the recommendations, considering the results of ranking of geothermal fields. The yearly progress of the integrated development plan (the Road Map) is shown in Figure 5.

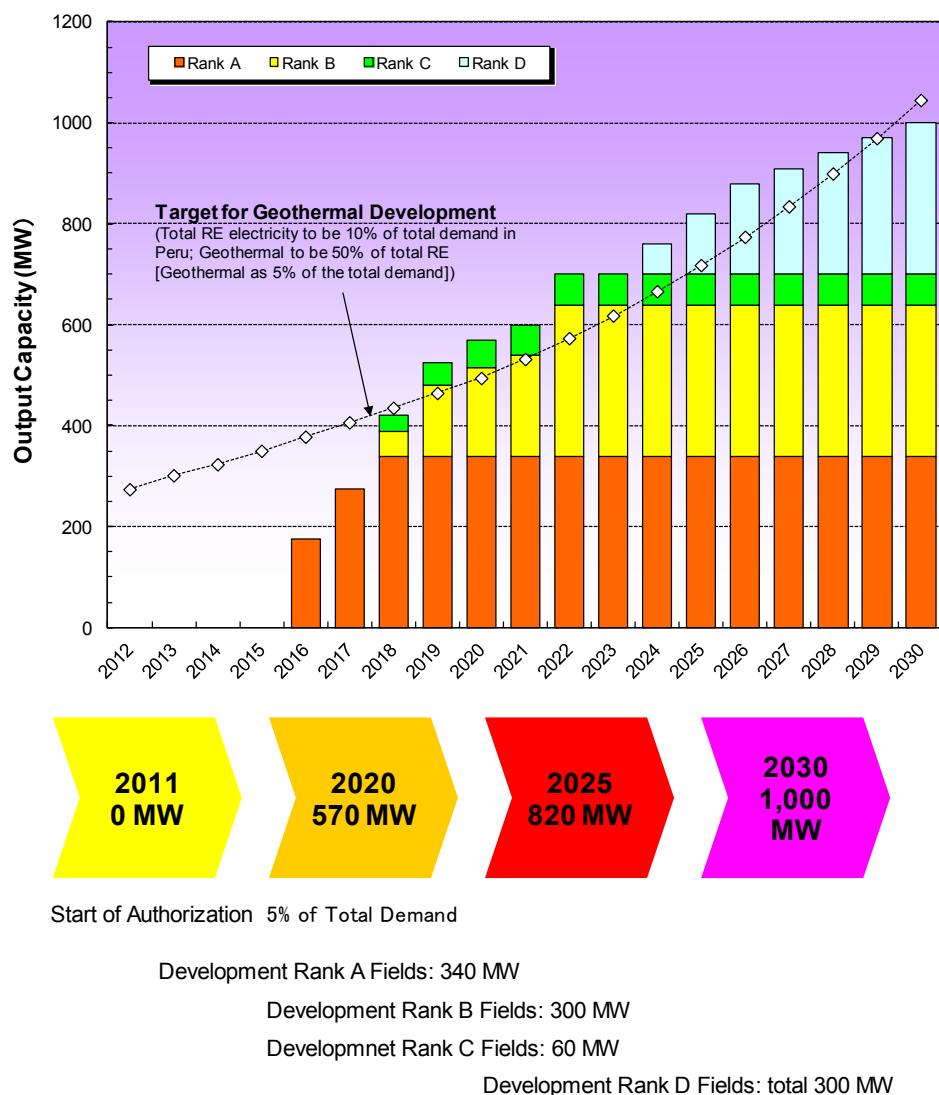


Figure 5: Road Map of geothermal power development in Peru

The timing for commissioning geothermal power generation were determined in such a way that the total output could catch up with the 5% of total electricity demand as early as possible. It was assumed that the load factor of future power plants would be 85%. The earliest commissioning of a geothermal power plant would be 2016 even for the Rank A fields which have been granted the authorization for exploration in 2011. This is because there is need of three years for exploration activities and thereafter three years will be necessary for plant construction activities. It is assumed that two more years will be necessary for the commissioning power generation at Rank B fields, that is, by 2018. For Chivay-Pinchollo field where the development scale is bigger than others, the first period of development is assumed to be completed in 2018, and the second period of development is assumed to be finished 2022. For Rank C fields, the earliest period for commissioning power generation is assumed to be 2018, since more time will be required compared to those of Rank A fields for investigation and confirmation of geothermal resources. The resource development in Rank D fields (Rank D-1 and D-2) largely depends on the progress of future studies and it is difficult to estimate the commencement period of power generation in Rank D fields. Thus the commencement period for Rank D fields is assumed to be not earlier than 2024.

The milestones in the intended development Road Map were set as follows: 570 MW in 2020, 820 MW in 2025, and 1,000 MW in 2030. For the realization of the objectives, proper managements and instructions must be given to the exploration activities practiced by private companies, and it is desirable for the government of Peru to support or to participate in the exploration activities when the exploration studies do not work effectively. In addition, the Road Map should be revised and updated if necessary according to the progress of the exploration/development activities.

12. CONCLUDING REMARKS

After the enactment of new Regulation of the Organic Law of Geothermal Resources in April 2010 and up to February of 2012 when the report was submitted to Peruvian authorities, MINEM extended exploration authorization to 20 projects (out of 98 applications) for exploration proposed by four companies (Canadian, Australian, Peruvian and an American). As of today (May 2014) unfortunately the 20 projects there has not been significant progress. Apart of some surface surveys in several of the geothermal areas, administrative procedures for obtaining environmental permits have been carried out in most of the case. There also has been the ceding of rights to other companies. Till today no application for the concession of power generation has been made. A company from the Philippines, (that purchased exploration rights from another concessioner) will likely make progress in the initial stages of resource exploration.

To overcome the current situation and to promote the utilization of geothermal energy in Peru, more aggressive contribution of the governmental organizations into the geothermal exploration and development is advisable. One way to improve progress would be the implementation of a pilot geothermal power project by a state-own enterprise so as to encourage the private sector for a more aggressive geothermal development.

REFERENCES

Battocletti, L.: Database of Geothermal Resources in Latin American & the Caribbean, (1999).

Japan Bank for International Cooperation (JBIC) - West Japan Engineering Consultants, Inc. (West JEC): Estudio de Pre-Factibilidad Campo Geotérmico de Calientes, Tacna, Perú: Informe Final, (2008).

Japan External Trade Organization (JETRO) - West Japan Engineering Consultants, Inc. (West JEC): Study on Geothermal Power Plant Construction Project, in the Borateras Field, Peru: Final Report, (2008)

Japan International Cooperation Agency (JICA) - West Japan Engineering Consultants, Inc. (West JEC): The Master Plan for Development of Geothermal Energy in Peru, Final Report, (2012).

Keary P. and Vine F.J.: Global Tectonics, *Blackwell Science Ltd.*, second edition, (1996).

Kono, M., Fukao, Y. and Yamamoto, A.: Mountain Building in the Central Andes, *J. Geophysical Res.*, **94**, (1989) 3891-3905.

Vargas, V. and Cruz, V.: Geothermal Map of Perú, *Proceeding of World Geothermal Congress 2010*, (2010).